THE OBJECTIVE PRISM.

By EDWARD C. PICKERING.

(*Read April 20, 1912.*)

Three methods may be employed for studying the spectra of the stars. First, the slit spectroscope. This is the method most widely used. The light of the star is concentrated on the slit of the spectroscope, and the linear spectrum widened, if necessary, by a cylindrical lens, or by moving the image of the star. Secondly, by the diffraction grating. As in the first method, the image of the star is concentrated on the slit. But little use has been made of this, and other diffraction methods in studying stellar spectra, owing to the great loss of light. Third, the objective prism. A prism of small angle is placed over the objective of the telescope, and the image of every star in the field is thus spread out into a linear spectrum. Any desired width may be given by allowing the star to traverse the plate slowly, parallel to the edges of the prism. This method cannot well be applied to reflectors, or to other telescopes of large size, owing to the size of prism required. Another objection, in the case of reflectors, is that the prism must be placed so far from the mirror that the definition is injured. These difficulties may be remedied by the focal plane spectroscope, in which the cone of rays from the star is rendered parallel by a concave lens, then passed through a mirror, and brought to a focus by a convex lens. All the light falling on a large mirror may thus be concentrated into a small space, so that the spectrum of a very faint star may be photographed. But little use has been made of this method, although it appears to have great possibilities.

The principal advantages of the objective prism are the small loss of light, and the large number of stars which may be photographed simultaneously. Also, that it is not necessary to follow, as when photographing star charts. The best authorities claim

that of the entire light entering the telescope, less than one per cent. reaches the photographic plate, when a slit spectroscope is used. The proportion of light transmitted by the objective prism must be at least fifty times as great. In fact, the principal loss of light is from the absorption of the objective. Consequently, far fainter stars can be photographed with an objective prism than with a slit spectroscope, the difference amounting to several magnitudes. Another great advantage of the objective prism is that the spectra of all the stars in the field of the telescope can be photographed simultaneously, while with a slit spectroscope only one star can be taken at a time. With the Harvard 8-inch doublet as many as three or four hundred spectra are often photographed on a plate, including all stars of the ninth magnitude and brighter, in a region ten degrees square.

A comparison spectrum cannot be used with an objective prism, and it is accordingly difficult to obtain absolute wave-lengths, which are needed to determine the motion of stars in the line of sight. This constitutes the principal objection to the objective prism. Various plans have been proposed to remedy this difficulty, and how far they are successful will be described by another speaker. This does not affect the ordinary measures of wave-lengths, as hydrogen lines are present in the spectra of nearly all the stars, and since these lines are affected by the motion, other lines can be referred to them.

The first photograph of the lines in the spectra of the stars was taken by Dr. Henry Draper of New York. In 1886, Mrs. Draper established, at the Harvard College Observatory, the Henry Draper Memorial, to prosecute the study of stellar spectra. The objective prism has been used almost exclusively in this work. Two photographic doublets of eight inches aperture have been mounted, one at Cambridge, the other at Arequipa, Peru. With these the entire sky has been covered many times. On one plate more than a thousand spectra were classified. The late Williamina P. Fleming, Curator of astronomical photographs, from an examination of these plates, discovered several thousand objects having peculiar spectra. In fact, probably few bright objects of this class escaped

her. Of the nineteen new stars, known to have appeared during the progress of this work, she discovered ten, and five more were found by other observers here. In this work also, the number of stars of the peculiar class known as fifth type, has been increased from seventeen to one hundred and eight.

For a more detailed study of the bright stars, prisms have been attached to the 11-inch Draper Telescope at Cambridge, and to the 13-inch Boyden Telescope at Arequipa. Spectra of the brightest stars have thus been obtained, six inches long, and half an inch wide, showing at least five hundred lines. Prisms twenty-four inches in diameter have been used with the Bruce Telescope in Arequipa, and sixteen inches in diameter with the Metcalf Telescope in Cambridge. The latest and largest investigation undertaken here, as part of the Henry Draper Memorial, is a catalogue giving the class of spectrum of a hundred thousand stars of the eighth magnitude and brighter, shown on the photograph taken with the 8-inch doublets. The classification of spectra used in the Draper Memorial, has been accepted by the superintendents of the principal nautical almanacs in their standard catalogue of three thousand stars, and also at the leading observatories. The preparation of the catalogue mentioned above has been undertaken by Mrs. Fleming's successor, Miss Annie J. Cannon, who has devoted a large part of her time during the last fifteen years to the detailed study of stellar spectra. Her classification of one thousand stellar spectra published in Volume 28 of the *Harvard Observatory Annals,* occupied her for three years. To complete, in a reasonable time, a catalogue of one hundred thousand spectra evidently required the most careful study of the methods of "scientific management." As a first step, her contribution to the work, which required the greatest skill, was reduced from one hundred to six per cent., the remainder being performed as a great piece of routine work, by less experienced assistants. The utmost care has been taken to maintain the highest degree of accuracy, the probable error of the result for each star being about a tenth of one interval, corresponding to four one-hundredths of a stellar magnitude. Miss Cannon is now classifying five thousand spectra a month, and has

already classified twenty-seven thousand spectra. The completed catalogue will fill four of the quarto volumes of the *Annals* of the observatory, of about two hundred and fifty pages each, and will give the class of spectrum of nearly all of the stars of the eighth magnitude and brighter, besides many others. Some of these are so faint that they are not contained in the *Cape Photographic Durchmusterung.*

Dr. Draper thus placed in our hands a wonderful tool for analyzing the stellar universe. His memorial furnishes not only a permanent record in print of great extent, but, through the collection of photographs, will permit in the future a vastly greater number of facts to be derived from them.

PROC. AMER. PHIL. SOC., LI. 207 J, PRINTED JAN. 17, 1913.